PATENT SPECIFICATION

DRAWINGS ATTACHED.

Inventor:—EDWARD PETER MORAN.

1,159,777

Prüfstoff
Kl.
Gr. 36/05

1,159,777

Date of Application and filing Complete Specification: 10 April, 1968. No. 17266/68.

Application made in United States of America (No. 631,383) on 17 April, 1967.

Complete Specification Published: 30 July, 1969.

Index at Acceptance:—**H4** J(24A1B, 24A3).

Int. Cl.:—H 04 b 3/02.

COMPLETE SPECIFICATION.

Signal Transmission Systems.

We, TEXTRON INC., a Corporation organized under the Laws of the State of Delaware, U.S.A., of 10 Dorrance Street, Providence, State of Rhode Island, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a signal transmission system for coupling the output of a high internal impedance source over a cable to a remote point in a manner avoiding the usual adverse effects of cable capacitance and leakage resistance.

It is often necessary to couple the signal from a high impedance source, such as a piezoelectric transducer, over a long length of cable to a remote utilization point. It is well known that severe limitations are placed upon the distance that can be covered in view of the cable capacitance and its leakage resistance. Numerous attempts have been made in the past to overcome this difficulty, but all have one or more disadvantages or limitations.

The present invention provides a system which is less sensitive to cable capacitance and leakage, thereby enabling longer cable lengths to be employed. The system provides a low impedance termination at the utilization point minimizing sensitivity to electrical pick-up by the cable and to noise induced in the cable by flexing at low frequencies. The frequency response of the system is not adversely affected by the normal values of cable leakage resistance and cable capacitance.

Although the invention described herein may be employed in connection with the transmission of signals originating from a variety of high impedance electrical sources, its most important application now known is in connection with the utilization of signals generated by charge generating sources as, for example, a piezoelectric transducer. It will be apparent that the invention can be employed to advantage in transmitting signals from condenser microphones, temperature transducers of the pyroelectric type, and the like.

According to the invention, there is provided a signal transmission system comprising means for converting an input voltage signal to an outut current signal, the means having a high input impedance and input terminals for connection to the source and having a two-terminal output for connection to one end of the cable; a source of voltage regulated D.C. energy; a fixed impedance; a variable impedance device; means connecting in series the source of regulated energy, fixed impedance, and variable impedance for connection across the other end of the cable; means connected across the series arrangement of source and impedances responsive to the voltage thereacross for controlling the variable impedance in a direction tending to maintain constant the last mentioned voltage; and means coupled to the fixed impedance for providing an output voltage as a function of the current flowing through the fixed impedance.

It is believed that the invention will be better understood after reading the following detailed description thereof with reference to the appended drawings in which:

Figure 1 is a schematic diagram of an embodiment of the system; and

Figure 2 is a fragmentary schematic diagram showing a modification of the system of Figure 1.

Referring now to Figure 1 of the drawing, a piezoelectric transducer 10 is shown connected to the input of a high input impedance amplifier encompassed within the outline box 11. The amplifier 11 may also be considered a voltage-to-current converter. A two-conductor transmission cable 12 having distributed capacitance and leakage resistance connects the amplifier 11 to the distant point and across a voltage sensing and regulator control element within the outline box 13. In series with one conductor of the cable 12 is a series regulator element, shown within box 14, controlled by the voltage sensing element 13. A voltage regulated D.C. power supply 15 is connected in series with an impedance 16 to the series regulator element 14, as shown. An amplifier within box 17 has its input connected across the impedance 16 while obtaining energizing power from the power supply 15. A network of capacitor 18 and resistor 19 connects the output of amplifier 17 to a pair of output terminals 20.

Considering the amplifier 11 in greater detail, it has input terminals 21 and 22 for connection to the piezoelectric transducer 10 or other source. Terminal 22 is joined by a conductive connection 23 to an output terminal 24 for the amplifier, it being assumed that amplifier 11 is to be located closely adjacent the transducer 10. The input terminal 21 is connected by lead 25 to the gate electrode 26 of a field effects transistor 27. The source electrode 28 of transistor 27 is connected through a resistor 29 to the conductive connection 23, as shown. The electrode 28 is also connected through a capacitor 30 to the junction between resistors 31, 32, and 33. Resistor 33 connects gate 26 to said junction while the resistors 31 and 32 constitute a voltage divider connected between the conductive connection 23 and the output terminal 34. The output stage of amplifier 11 includes a current control device in the form of an N-P-N transistor 35. As shown, the base electrode 36 of transistor 35 is connected to the drain electrode 37 of the field effects transistor 27. The collector electrode 38 of transistor 35 is connected to the junction between resistor 29 and source electrode 28. The emitter electrode 39 is connected to terminal 34.

As shown, the cable 12, having two conductors, connects the output terminals 24 and 34 of amplifier 11 to the input terminals 40 and 41 of the utilization circuit which may be several hundred feet away. Terminal 41 is connected to the ground or reference line 42. The impedance 16, it should be observed, includes a resistor 43 connected in parallel with a capacitor 44. The series regulator elements 14 is shown as consisting of a P-N-P transistor 45.

A series circuit can now be traced from terminal 40 over a conductor 46 to the emitter electrode 47 of transistor 45, and then from collector electrode 48 through the parallel arrangement of resistor 43 and condenser 44 over connection 49 to the negative terminal of the voltage regulated D.C. power supply 15. The positive terminal of the supply 15 is connected to the ground line 42.

Current is supplied from the negative terminal of supply 15 over connection 49 through a load resistor 50 to the collector electrode 51 of a further P-N-P transistor 52. Resistors 53 and 54 are connected in series across the supply 15 with their junction connected to the emitter electrode 55 of transistor 52. The base electrode 56 of transistor 52 is connected to the junction between resistors 57 and 58 which are connected between terminals 40 and 41. The resistor 57 is shunted by a bypass capacitor 59.

The output amplifier 17 includes an N-P-N transistor 60 and a P-N-P transistor 61 connected in cascade. As shown, the base electrode 62 of transistor 60 is connected by a conductive connection directly to the junction between resistor 43 and the collector electrode 48 of transistor 45. The emitter electrode 63 of transistor 60 is connected through a resistor 64 to the opposite end of resistor 43. Collector electrode 65 of transistor 60 is directly connected to the base electrode 66 of transistor 61. The collector electrode 67 of transistor 61 is connected to the junction between resistor 64 and emitter electrode 63. The emitter electrode 68 of transistor 61 is connected through resistor 69 and conductive connection 70 to the ground lead 42. The connection 70 is also connected to one of the output terminals 20. The other terminal of the pair 20 is connected through resistor 19, as shown, to the conductive connection 70. Finally, the capacitor 71 is connected between the base electrode 66 and the conductive connection 70.

It should now be apparent that the transistors in the amplifier circuit 11 receive their energizing power over a circuit that can be traced from the negative terminal of power supply 15 through conductor 49, resistor 43, transistor 45, connection 46, terminal 40, a conductor of cable 12 (preferably the inner conductor where cable 12 is of the co-axial type), terminal 34, through the transistors 35 and 27 to the load resistor 29, then from terminal 24 through the outer conductor of cable 12 to terminal 41 and over the ground connection 42 to the positive terminal of the supply 15. Fluctuation in voltage appearing at terminals 40

and 41 due to change in the conductivity of transistor 35 as a result of a signal obtained from transducer 10 is applied through the network consisting of resistors 57 and 58 and capacitor 59 to the base electrode 56 of transistor 52. This fluctuation in voltage is compared with a reference voltage applied to the emitter electrode 55 from the voltage divider consisting of resistors 53 and 54. It will be noted that the resistors 53 and 54 are connected across the regulated power supply 15. Thus, in well known manner, the conductivity of transistor 52 will be varied as a function of the voltage appearing between terminals 40 and 41.

Variation in the conductivity of transistor 52 will cause a controlling voltage to appear across resistor 50. This, in turn, determines the conductivity and, therefore, the impedance of transistor 45 to current flowing therethrough to terminal 40. It should now be apparent that the circuit consisting of the elements in outline boxes 13 and 14 constitutes a voltage regulator which will tend to maintain substantially constant the voltage applied to terminals 40 and 41. However, the current supplied through cable 12 to amplifier 11 will vary. This variation in current will cause a signal voltage to appear across resistor 43 which, in turn, is amplified by the two stages of amplification in amplifier 17.

It will be understood that the transistors 27 and 35 constitute a unipolar-bipolar cascade amplifier which, by reason of the field effects transistor, has a very high input impedance. The transfer characteristic of this amplifier or electron device 11 is controlled by the signal obtained from the piezoelectric source 10.

A satisfactory embodiment of the circuit of Figure 1 was constructed with the circuit constants set forth in the following tabulation. It will be understood that these values are only exemplary.

Resistors

Ref. No.	Ohms
19	100 K
29	1,000
31	3.3 M
32	2.2 M
33	22.0 M
43	1,000
50	20.0 K
53	5,620
54	1,580
57	5,620
58	5,620
64	1,000
69	1,000

Capacitors

Ref No.	mfd.
18	50
30	3.3
44	2200×10^{-6}
59	1
71	100×10^{-6}

Transistors

Ref. No.	Type
27	2N2606
35	2N3904
45	2N3906
52	2N3906
60	2N3904
61	2N3906

Power Supply 15—42 volts

In the above tabulation $K = \times 10^3$ and $M = \times 10^6$.

The length of cable that can be used with the system described in conjunction with Figure 1 can be increased considerably by inserting additional voltage regulator circuits at intermediate points along the cable as shown in Figure 2.

As seen in Figure 2, a four-terminal voltage regulator circuit within the outline box 72 is inserted in the cable between the terminals 24, 34 on the one hand and the terminals 40, 41 on the other hand. The regulator circuit includes a series regulator element or variable impedance in the form of a P-N-P transistor 73 connected between terminals 74 and 75. The voltage divider consisting of resistors 76 and 77 is connected between terminal 74 and a terminal 78, as shown. The junction of resistors 76 and 77 is connected to the base electrode 79 of another P-N-P transistor 80. The collector electrode 81 of transistor 80 is connected to the base electrode 82 of transistor 73 and through a load resistor 83 to the terminal 75. A biassing network consisting of resistors 84 and 85 and capacitor 86 is connected, as shown, between terminal 75 and another terminal 87. The emitter electrode 88 of transistor 80 is connected to the com-

mon junction of the three elements of the biassing network. Transistor 73 has its collector electrode 89 connected to terminal 75 and its emitter electrode 90 connected to terminal 74.

In operation, the transistors 73 and 80 of Figure 2 function in very much the same manner as the respective transistors 45 and 52 in Figure 1.

Although only one in-line regulator is shown in Figure 2, several may be used at spaced locations.

Typical circuit constants for the circuit of Figure 2, are: resistors 76, 77 and 85—5,620 ohms each; resistors 83 and 84—10.0 K ohms each; capacitor 86—10 microfarad; transistors 73 and 80—type 2N3906.

WHAT WE CLAIM IS:—

1. A signal transmission system for coupling the output of a high internal impedance source over two conductors to a distant point, characterized in that a source of regulated D.C. voltage is coupled in series with a normally fixed impedance to one end of said two conductors for supplying electric energy thereto, an electron device is coupled to the other end of said two conductors for receiving its energization and for controlling the current flowing therethrough, an arrangement is provided for connecting said high internal impedance source to said electron device for controlling the transfer characteristic of the latter, apparatus is coupled to the first end of said conductors for maintaining substantially constant the voltage applied thereto independent of variation in current flow, and the output from the system is obtained across said fixed impedance as a function of the current passing therethrough.

2. A signal transmission system according to Claim 1, characterized in that the electron device comprises an amplifier circuit including a current control device having at least three electrodes, a first and second one of said electrodes being coupled to the two conductors for receiving the energization, and the third electrode along with one of said first two electrodes being arranged for receiving the output from the high impedance source.

3. A signal transmission system according to Claim 1 or 2, characterized in that the electron device comprises a unipolar-bipolar cascade transistor amplifier, the unipolar transistor being of the field effects type and having its gate and source electrodes arranged to receive the output from the high impedance source.

4. A signal transmission system according to Claim 1, 2 or 3, characterized in that at least one four-terminal voltage regulator circuit is inserted in line with the two conductors at an intermediate point thereof.

5. A signal transmission system according to Claim 4, characterized in that the four-terminal circuit comprises a variable impedance device connected in series with one of the two conductors, and an arrangement connected between said conductors and coupled to said variable impedance device for controlling the impedance of the latter in response to fluctuation of the voltage between said conductors to tend to maintain said voltage constant.

6. A signal transmission system according to any of the preceding claims, characterized in that the electron device constitutes the output stage of a high input impedance amplifier.

7. A signal transmission system substantially as described with reference to Figure 1 of the drawings.

8. A signal transmission system substantially as described with reference to Figures 1 and 2 of the drawings.

For the Applicants,
F. J. CLEVELAND & COMPANY,
Chartered Patent Agents,
Lincoln's Inn Chambers,
40/43 Chancery Lane,
London, W.C.2.

Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon), Ltd.—1969.
Published at The Patent Office, 25 Southampton Buildings, London, W.C.2,
from which copies may be obtained.

1159777 COMPLETE SPECIFICATION

1 SHEET

This drawing is a reproduction of the Original on a reduced scale

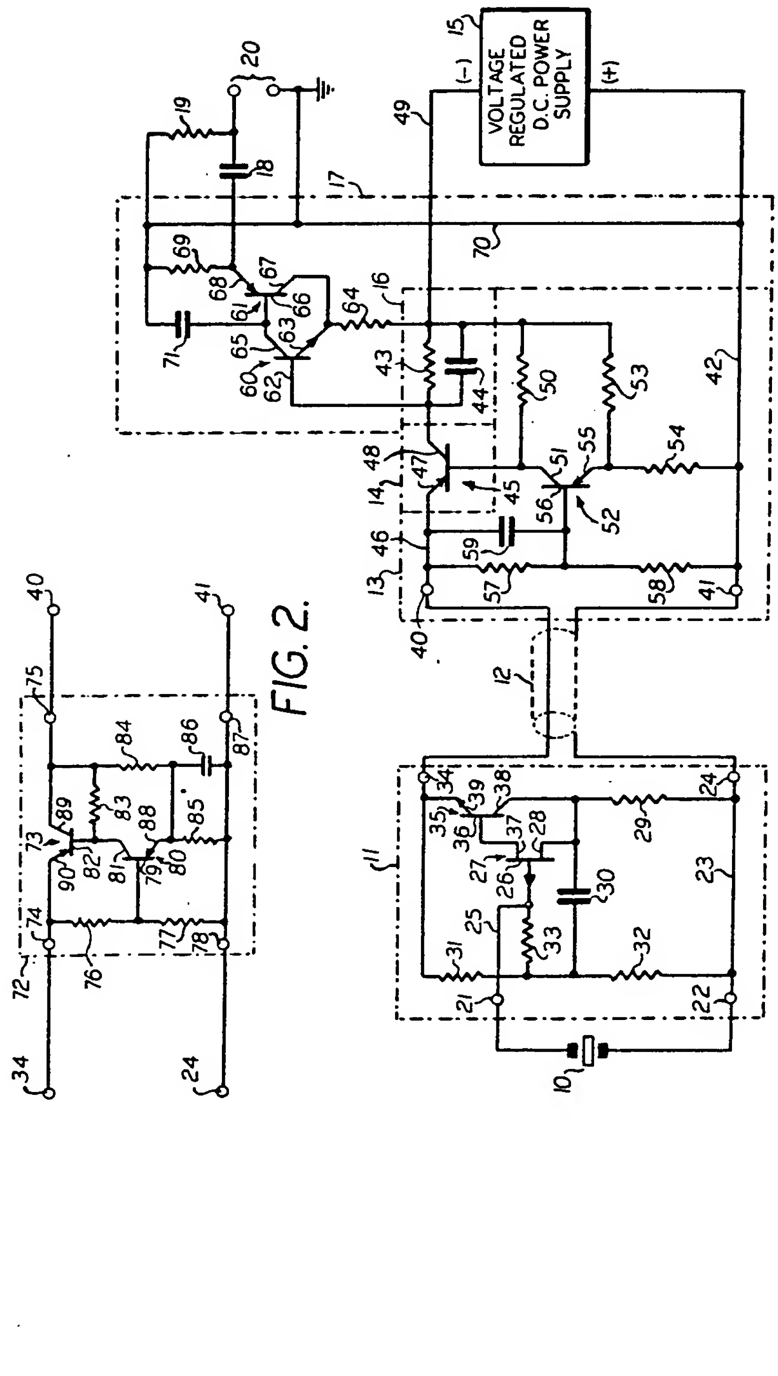

FIG. 1.

FIG. 2.